Reproductive biology of *Lophius budegassa* (Lophiidae) in the North Aegean Sea

by

C. Cigdem YIGIN*, Ali ISMEN & Mukadder ARSLAN (1)

Abstract. – The reproductive biology of black-bellied anglerfish, *Lophius budegassa* Spinola, 1807, was described for the first time in the Saros Bay, in the North Aegean Sea, between September 2006 and September 2008. A total of 862 specimens (15.7-107.0 cm) was sampled. Sex-ratio, spawning period and length at first sexual maturity were determined. The F:M sex-ratio was close to 1.5. Using gonadosomatic index and gonadal macroscopic observation, the spawning period was estimated to occur between December and March. Length at first sexual maturity was 42.5 cm for males and 58.8 cm for females.

Résumé. – Biologie de la reproduction de la baudroie rousse, *Lophius budegassa* Spinola, 1807, au nord de la mer Égée.

La biologie de la reproduction des baudroies rousses, *Lophius budegassa* Spinola, 1807 au Nord de la mer Égée est ici décrite pour la première fois entre septembre 2006 et septembre 2008. Au total, 862 spécimens (15,7-107,0 cm) ont été analysés. Le sex-ratio, la période de reproduction et la taille de première maturation sexuelle ont été déterminés. Le sex-ratio F:M est proche de 1,5. En utilisant l'index gonadosomatique et l'observation macroscopique des gonades, la période de ponte est estimée s'étaler de décembre à mars. La taille de première maturation sexuelle est de 42,5 cm pour les mâles et de 58,8 cm pour les femelles.

© SFI
Received: 15 Oct. 2013
Accepted: 20 Jan. 2015
Editor: K. Rousseau

Key words
Lophiidae
Lophius budegassa
North Aegean Sea
Reproduction
Spawning
Maturity

Black-bellied anglerfishes, *Lophius budegassa* Spinola, 1807, are a typical bottom-living species with economical importance, living at a depth range between 70 m and 800 m. They are found throughout the Mediterranean Sea and the North-Eastern Atlantic, from the British Isles to Senegal (Duarte *et al*., 2001; La Mesa and De Rossi, 2008). Anglerfish species are relatively common in Turkish waters, with a total catch of 360 tonnes in 2008, followed by 219 tonnes in 2010 and 204 tonnes in 2013 (TurkStat, 2013). In Turkish waters, anglerfish species are captured by the trawl fleets, which actuate in the different regions but their numerical addition is small. Although anglerfish species are not a target species in the fisheries, they have commercial importance for human consumption and are exported fresh or frozen in Turkey.

In European Atlantic waters, age and growth (Landa *et al*., 2001, 2008a), reproduction (Afonso-Dias and Hislop, 1996; Duarte *et al*., 2001), feeding habits (Laurenson and Priede, 2005; Preciado *et al*., 2006) and geographical/depth distribution (Azevedo, 1995; Pereda and Landa, 1998; Landa *et al*., 2008b) of black-bellied anglerfish have been studied. Since 2000, studies on the biological characteristics of anglerfish in the Mediterranean have remarkably increased (Ungaro *et al*., 2002; Maravelias and Papaconstantinou, 2003; García-Rodríguez *et al*., 2005; La Mesa and De Rossi, 2008; Negzaoui-Garali and Ben Salem, 2008; Negzaoui-Garali *et al*., 2008; Carlucci *et al*., 2009; Colmenero *et al*., 2010, 2013; Stagioni *et al*., 2013).

Despite the economic significance of *L. budegassa*, no information on its reproductive biology and dynamics is available in the North Aegean Sea. The lack of information on reproductive biology of *L. budegassa,* together with decreasing trends in landings, raised concerns on population structure and successful management of stocks in the future. In this regard, the main objective of the present study is to provide information on reproductive aspects of *L. budegassa* with a focus on sex-ratio, spawning period and length at first sexual maturity.

MATERIAL AND METHODS

Specimens were collected by means of commercial trawls between September 2006 and September 2008 in the Saros Bay, in the North of the Aegean Sea at depths between 5 and 616 m (Fig. 1). Trawl times lasted for approximately 30 min with moderate trawl speeds (2.5 knots.h^{-1}). A total of 862 blackbellied anglerfish were sampled. All fish were measured for total length (TL) in centimetres and total weight (TW), gonad weight (G) and somatic weight (SW = TW – GW) in grams. The maturity stage was determined using the sexual classification scale of Duarte *et al.* (2001). Five stages were observed: stage I, immature; stage

---

(1) Çanakkale Onsekiz Mart University, Marine Science and Technology Faculty, Çanakkale-Turkey.
[alismen@yahoo.com] [mukadderarslan@gmail.com]
* Corresponding author [cyigin@hotmail.com]

II, maturing; stage III, mature; Stage IV, spawning and stage V, post-spawning.

Spawning period was determined through monthly observations of the macroscopic development stages, and by the gonadosomatic index (GSI), calculated monthly for each sex, by the equation: GSI = (Gonad weight / Body weight) x 100.

The length at which 50% of fish were sexually mature (L_{50}), or length at first maturity, was estimated for reproductively active fish (Stages 3-5) per cm size-class, by fitting a logistic function using the Newton algorithm (Microsoft Excel solver routine) which is defined as: $P(1) = 1 / 1 + e^{-(a + b1)}$ where P(1) was the proportion of mature fish at length 1, and a and b the parameters of the logistic equation (Piñeiro and Saínza, 2003). Sex-ratios were compared to the 1:1 proportion by using the chi-square (χ^2) goodness fit test (Hammer *et al.*, 2001). The difference between the size structure in the females and males was analysed by means of the non-parametric Kolmogorov-Smirnov test (Carlucci *et al.*, 2009). The one-way analysis of variance (ANOVA) test was used to compare the differences in GSI values between males and females (Zar, 1999).

RESULTS

Sex-ratio

A total of 862 black-bellied anglerfish were collected, including 526 females and 336 males, with a sex-ratio of 1.57:1. The overall sex-ratio was significantly different from the expected 1:1 ratio (df = 1, $\chi^2 =$ 41.88; $P < 0.05$). The number of sampled individuals by length is shown for both sexes in figure 2. The size ranges sampled were 15.7-75.7 mm TL and 17.1-107.0 mm TL for males and females, respectively. The size structures were significantly different between males and females (Kolmogorov-Smirnov Z (females): 1.91, Z (males): 1.53; $P < 0.05$). The quantity of males and females are coarsely equal in the smaller lengths. Males are more numerous from about 30-35 cm length interval and above 40 cm, females outnumber males.

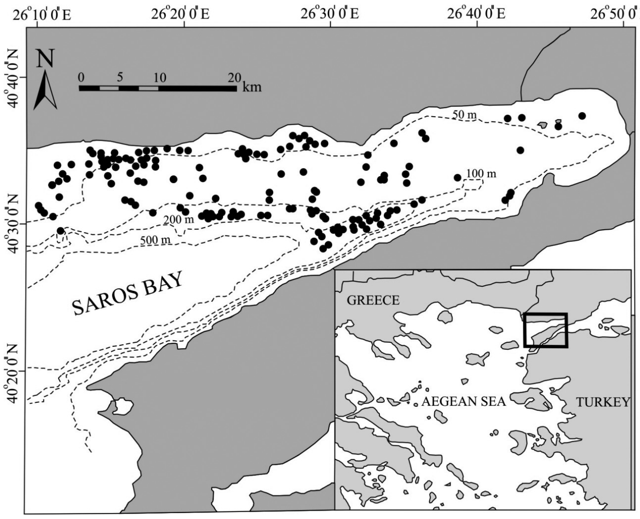

Figure 1. - Map of the study area; Saros Bay, in the North Aegean Sea. ● Sampling stations.

Spawning period

Figure 3 shows the percentage of each maturity stage by sex for *L. budegassa* at each monthly sampling. It shows that male ripening in (Stage IV) black-bellied anglerfish occurred from January to March with a low percentage in May (Fig. 3A). The percentage of maturing females (Stage III) increased from October to December and thereafter only appeared in low numbers from March to August. Spawning females (Stage IV) were observed in December through January (Fig. 3B). Post-spawning females (Stage V) were most abundant between January and March (Fig. 3B).

The gonadosomatic index (GSI) was used to estimate the reproductive period, which was based on monthly samples. The GSI (one-way ANOVA) showed a significant difference between males and females (df = 1, F = 6.39, $P < 0.05$). In males, maximum GSI value of 1.20 was reached in January (Fig. 4A). For females, mean monthly GSI values were low between February and December (GSI = 0.80-0.72) and peaked in January (GSI = 6.04) (Fig. 4B), which coincided with the months of greatest incidence of "spawning" fish (Fig. 3B). The results of GSI and maturity stage indicate that the spawning period for black-bellied anglerfish in the study area was from December to March.

Length at first sexual maturity

The data on maturity stages indicates that length at 50% maturity (L_{50}) was 42.5 cm for males (Fig. 5A) and 58.8 cm for females (Fig. 5B).

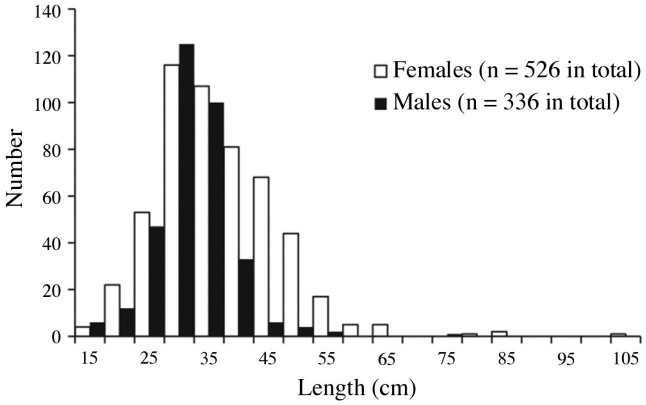

Figure 2. - Length-number distribution of *Lophius budegassa* sampled in the Saros Bay by commercial vessel between September 2006 and September 2008.

DISCUSSION

In the study area, the sex-ratio of *L. budegassa* was found to be 1:1.57 (336 males and 526 females). The sex-ratio values of *L. budegassa* was similar to the other studies in the Atlantic and Scottish waters (Duarte *et al*., 2001; Laurenson *et al*., 2008; Landa *et al*., 2014) and for the Spanish Mediterranean (García-Rodríguez *et al*., 2005). In our study, size classes of *L. budegassa* were significantly different between males and females. Duarte *et al*. (2001) found that the sex-ratio varies with length and females attain a greater size than males in *L. budegassa* species. Carlucci *et al*. (2009) reported that the size structures of blackbellied anglerfish females were significantly different from males and the mean sizes of females were significantly greater than males. The proportion of female *L. budegassa* in the Spanish Mediterranean

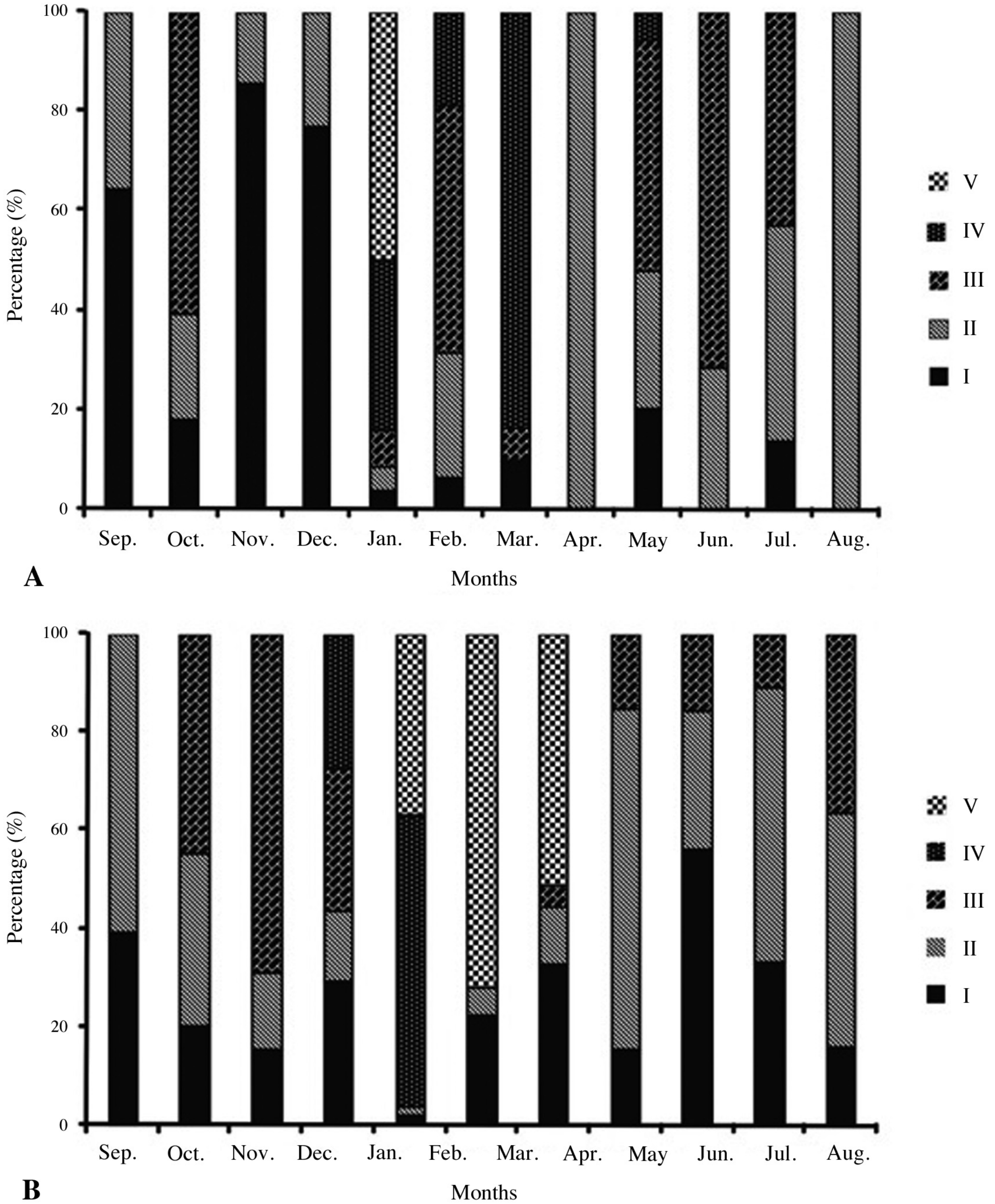

Figure 3. - Monthly percentage of each maturity stage for males (**A**) and females (**B**) black-bellied anglerfish. Maturity stages: I, Immature; II, Maturing; III, Mature; IV, Spawning; V, Post-Spawning.

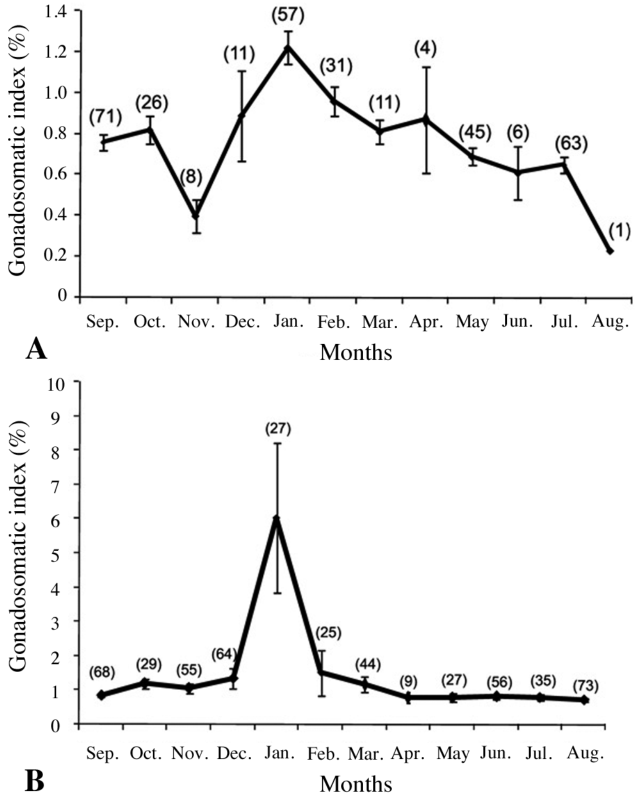

Figure 4. - Monthly variation of gonadosomatic index for males (**A**) and females (**B**) *Lophius budegassa* between September 2006 and September 2008. Vertical bars represent standard error with sample size values indicated between brackets.

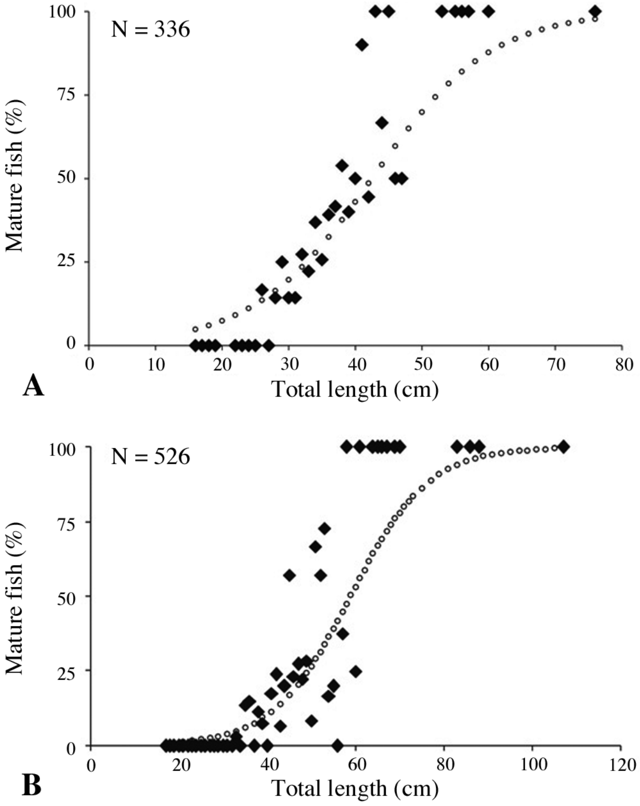

Figure 5. - Percentage of sexually mature males (**A**) and females (**B**) *Lophius budegassa* according to total length.

decreases with increasing depth that may reflect a seasonal segregation (García-Rodríguez *et al*., 2005). Laurenson *et al*. (2008) found that the proportion of *L. piscatorius* varies with both depth and season in Scottish waters. Several statements can explain this difference. Differentiation in growth rate between sexes can cause an unbalanced proportion, since the sex presenting faster growth rate will go through the most vulnerable smaller size phase quickly and, therefore decrease the predation proportion. Conversely, the sex with slower growth rate will be more likely to pass predation, with its abundance decreased disproportionately in next development phases (Vicentini and Araújo, 2003). Another important factor could be the sampling method. Bouchereau *et al*. (1989) indicated that this difference of sex-ratio could be due to selective fishing in relation to morphological and behavioural differences, that can affect the sampling in relation to the real population. Another factor that could influence sex-ratio is food availability. Landa *et al*. (2014) reported that variation of the sex-ratio may be related to reproductive and feeding migrations of each sex to different locations.

The estimated spawning period was mainly based on spawning (stage IV) and post-spawning (stage V) and GSI values in females and males. Therefore, the results suggest a main spawning period from December to March for blackbellied anglerfish. In females, spawning and post-spawning stages have been seen from December to March and in males from January to March (Fig. 3A, B). At the same time, GSI values in males were high except in August and November, while female GSI values were the highest in January (Fig. 4A, B). The spawning males can be seen almost all year around (Duarte *et al*., 2001; Landa *et al*., 2014), and this could increase the chances for a mature female to encounter

Table I. - Length at 50% maturity (L_{50}) of *Lophius budegassa* obtained by other authors.

Length maturity L_{50} (cm)		Region	Source
Females	Males		
56.2	37.6	Portuguese coasts	Azevedo (1996)
64.5	34.5	Bay of Biscay	Quincoces *et al*. (1998)
58.7	41.0	Northern Bay of Biscay	Quincoces (2002)
53.6	38.6	Atlantic Iberian Waters	Duarte *et al*. (2001)
70.4	49.4	Scottish Waters	Laurenson *et al*. (2008)
53.0	36.0	Northern Spanish Waters	Landa *et al*. (2014)
48.2	33.4	NW Mediterranean Sea	Colmenero *et al*. (2013)
58.8	42.5	Saros Bay	This study

a mature male and thereby enhances reproductive success (Armstrong *et al.*, 1992). Duarte *et al.* (2001) and Azevedo (1996) identified the main spawning period for *L. budegassa* in the Portuguese and Spanish Atlantic coasts to be from November to February and October to March, respectively. In the Bay of Biscay, the peak of spawning for *L. budegassa* was from May to July (Quincoces *et al.*, 1998). The common feature to spawn over several months, however, is reflected in the extended hatching period of larvae, which experienced different environmental conditions (La Mesa and De Rossi, 2008). According to Laurenson *et al.* (2008) and Landa *et al.* (2014), it was difficult to determine the spawning period of *L. budegassa* in Scottish waters and northern Spanish waters due to the lack of ripe female samples.

In our study, male and female lengths at 50% maturity were estimated at 42.5 cm and 58.8 cm, respectively (Fig. 5A, B). Previously published maturation data for *L. budegassa* is variable. The L_{50} ranged from 48.2 cm to 70.4 cm for females and from 33.4 cm to 49.4 cm for males (Tab. I) (Laurenson *et al.*, 2008; Colmenero *et al.*, 2013) and our results fall in the middle of these ranges. Studies on both *L. budegassa* and *L. piscatorius* have a scarcity of mature females in catches and the effects of factors such as migration, duration of the spawning phase, changes in catchability and methodologies (macroscopic analysis or histology) have previously been considered as potentially responsible for this situation. (Quincoces *et al.*, 1998; Duarte *et al.*, 2001; Laurenson *et al.*, 2008; Landa *et al.*, 2014).

This study provided new information on the reproductive biology of *L. budegassa* in the North Aegean Sea. In earlier studies, size at first sexual maturity and minimum landing size of the black-bellied anglerfish in the North Aegean Sea were not investigated. Currently, there are no restrictions on capture size and spawning season of *L. budegassa*. This information can be used for establishing regulations on anglerfish fisheries. Our findings indicated that the minimum capture size of anglerfish should be 59 cm. In addition, GSI data showed that spawning period of *L. budegassa* is between December and March. Further information on spawning grounds and migration patterns will be useful for understanding the life history of this species and for better management of *Lophius budegassa* stocks in the area.

Acknowledgements. – The present study was carried out with the financial support of TUBITAK 106Y035. The authors would like to thank the crew of the trawl vessel ‘Sahin Reis’ and all the staff who helped in the fieldwork and in the laboratory. We thank Dr. Umur Önal for improving English language.

REFERENCES

AFONSO-DIAS I.P. & HISLOP J.R.G., 1996. - The reproduction of anglerfish *Lophius piscatorius* Linnaeus from the north-west coast of Scotland. *J. Fish Biol.* (Suppl. A), 49: 18-39.

ARMSTRONG M.P., MUSICK J.A. & COLVOCORESSES J.A., 1992. - Age, growth, and reproduction of the goosefish *Lophius americanus* (Pisces: Lophiiformes). *Fish. Bull.*, 90: 217-230.

AZEVEDO M., 1995. - A statistical analysis of black monkfish catch rates in ICES Division IXa. *Fish. Res.*, 24: 281-289.

AZEVEDO M., 1996. - Contribution to the study of the biology of black monkfish, *Lophius budegassa*, Spinola (ICES Division VIIIc and IXa). *Boll. Inst. Port. Invest. Marít.*, Lisboa, 2: 5-13.

BOUCHEREAU J.L., JOYEUX J.C. & TOMASINI J.A., 1989. - Structure de la population de *Pomatoschistus microps* (Kroyer, 1838), Poisson, Gobiidés, dans la lagune de Mauguio (France). *Vie Milieu,* 39: 19-28.

CARLUCCI R., CAPEZZUTO F., MAIORANO P., SION L. & D’ONGHIA G., 2009. - Distribution, population structure and dynamics of the black anglerfish (*Lophius budegassa*) (Spinola, 1987) in the Eastern Mediterranean Sea. *Fish. Res.*, 95(1): 76-87.

COLMENERO A.I., AGUZZI J., LOMBARTE A. & BOZZANO A., 2010. - Sensory constraints in temporal segregation in two species of anglerfish, *Lophius budegassa* and *L. piscatorius*. *Mar. Ecol. Prog. Ser.,* 416: 255-265.

COLMENERO A.I., TUSET V.M., RECASENS L. & SÁNCHEZ P., 2013. - Reproductive biology of Black Anglerfish (*Lophius budegassa*) in the northwestern Mediterranean Sea. *Fish. Bull.*, 111: 390-401.

DUARTE R., AZEVEDO M., LANDA J. & PEREDO P., 2001. - Reproduction of anglerfish (*Lophius budegassa* Spinola and *Lophius piscatorius* Linnaeus) from the Atlantic Iberian coast. *Fish. Res.*, 51: 349-361.

GARCÍA-RODRÍGUEZ M., PEREDA P., LANDA J. & ESTEBAN A., 2005. - On the biology and growth of the anglerfish *Lophius budegassa* Spinola, 1807 in the Spanish Mediterranean: a preliminary approach. *Fish. Res.*, 71: 197-208.

HAMMER Ø., HARPER D.A.T. & RYAN P.D., 2001. - PAST: Paleontological Statistics software package for education and data analysis. *Palaeontol. Electron.*, 4(1): 1-9.

LA MESA M. & DE ROSSI F., 2008. - Early life history of the black anglerfish *Lophius budegassa* Spinola, 1807 in the Mediterranean Sea using otolith microstructure. *Fish. Res.*, 93(1-2): 234-239.

LANDA J., PEREDO P., DUARTE R. & AZEVEDO M., 2001. - Growth of anglerfish (*Lophius piscatorius* and *L. budegassa*) in Atlantic Iberian waters. *Fish. Res.*, 51: 363-376.

LANDA J., DUARTE R. & QUINCOCES I., 2008a. - Growth of white anglerfish (*Lophius piscatorius*) tagged in the Northeast Atlantic, and a review of age studies on anglerfish. *ICES J. Mar. Sci.,* 65: 72-80.

LANDA J., QUINCOCES I., DUARTE R., FARIÑA A. & DUPOUY H., 2008b. - Movements of black and white anglerfish (*Lophius budegassa* and *L. piscatorius*) in the northeast Atlantic. *Fish. Res.,* 94: 1-12.

LANDA J., ANTOLÍNEZ A., ÁMEZ M.A., BARRADO J., CASTRO B., CAÑÁS L., AUTÓN U., FARIÑA A.C. & HERNÁNDEZ C., 2014. - Preliminary observation on sexual maturity of black anglerfish (*Lophius budegassa*) in north-eastern Atlantic waters. *Deep-Sea Res., II*, 106: 225-231.

LAURENSON C.H. & PRIEDE I.G., 2005. - The diet and trophic ecology of anglerfish *Lophius piscatorius* at the Shetland Islands UK. *J. Mar. Biol. Ass. U.K.*, 85: 419-424.

LAURENSON C.H., DOBBY H., McLAY H.A., 2008. - The *Lophius budegassa* component of monkfish catches in Scottish waters. *ICES J. Mar. Sci.,* 65(7): 1346-1349.

MARAVELIAS C.D. & PAPACONSTANTINOU C., 2003. - Size-related habitat use, aggregation patterns and abundance of anglerfish (*Lophius budegassa*) in the Mediterranean Sea determined by generalized additive modelling. *J. Mar. Biol. Ass. U.K.*, 83: 1171-1178.

NEGZAOUI-GARALI N. & BEN SALEM M., 2008. - Morphological characters and meristic counts in two anglerfishes, *Lophius budegassa* and *L. piscatorius* (Osteichthyes: Lophiidae) from Tunisian coastal waters (central Mediterranean). *Ann. Ser. Hist. Nat.*, 18: 17-26.

NEGZAOUI-GARALI N., BEN SALEM M. & CAPAPÉ C., 2008. - Feeding habits of the black anglerfish, *Lophius budegassa* (Osteichthyes: Lophiidae), off the Tunisian coast (central Mediterranean). *Cah. Biol. Mar.*, 49: 113-122.

PEREDA P. & LANDA J., 1998. - Recuperación de dos ejemplares de rape blanco *Lophius piscatorius* Linnaeus, 1758 en el stock norte (divisiones VIIIc). *Bol. Inst. Esp. Oceanogr.*, 13(1/2): 15-24.

PIÑEIRO C. & SAÍNZA M., 2003. - Age estimation, growth and maturity of the European hake (*Merluccius merluccius* (Linnaeus, 1758)) from Iberian Atlantic waters. *ICES J. Mar. Sci.*, 60: 1086-1102.

PRECIADO I., VELASCO F., OLASO I. & LANDA J., 2006. - Feeding ecology of black anglerfish *Lophius budegassa*: seasonal, bathymetric and ontogenetic shifts. *J. Mar. Biol. Ass. U.K.*, 86: 877-884.

QUINCOCES I., 2002. - Crecimiento y reproducción de las especies *Lophius budegassa* Spinola 1807, y *Lophius piscatorius* Linneo 1758, del Golfo de Vizcaya. Ph.D. thesis, 258 p. Dept de Zoología y Dinámica Celular Animal, Univ. del País Vasco, Spain.

QUINCOCES I., SANTURTÚN M. & LUCIO P., 1998. - Biological aspects of black anglerfish (*Lophius budegassa*) in the Bay of Biscay waters during 1996-1997. *ICES*, cm 1998/O:47, 28 p.

STAGIONI M., MONTANINI S. & VALLISNERI M., 2013. - Feeding habits of anglerfish, *Lophius budegassa* (Spinola, 1807) in the Adriatic Sea, north-eastern Mediterranean. *J. Appl. Ichthyol.*, 29: 374-380.

TURKSTAT, 2013. - Turkish Statistical Institute. Fishery Statistics, Publication Number: 4349. 61 p. Turkey: Ankara.

UNGARO N., MARANO G., AUTERI R., VOLIANI A., MASSUTÍ E., GARCÍA-RODRÍGUEZ M. & OSMANI K., 2002. - Distribution, abundance and biological features of anglerfish (*Lophius piscatorius* and *Lophius budegassa*) (Osteichthyes: Lophiiformes) in the Mediterranean Sea. *Sci. Mar.*, 66: 55-63.

VICENTINI R.N. & ARAÚJO F.G., 2003. - Sex ratio and size structure of *Micropogonias furnieri* (Desmarest, 1823) (Perciformes, Sciaenidae) in Sepetiba Bay, Rio De Janeiro, Brazil. *Braz. J. Biol.*, 63(4): 559-566.

ZAR J.H., 1999. - Biostatistical Analysis. 4th edit., 663 p. NJ: Prentice Hall.